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Original Research Article

Studies on mechanical properties of isoro fibers mixed with calcium corbanate reinforced with polypropylene

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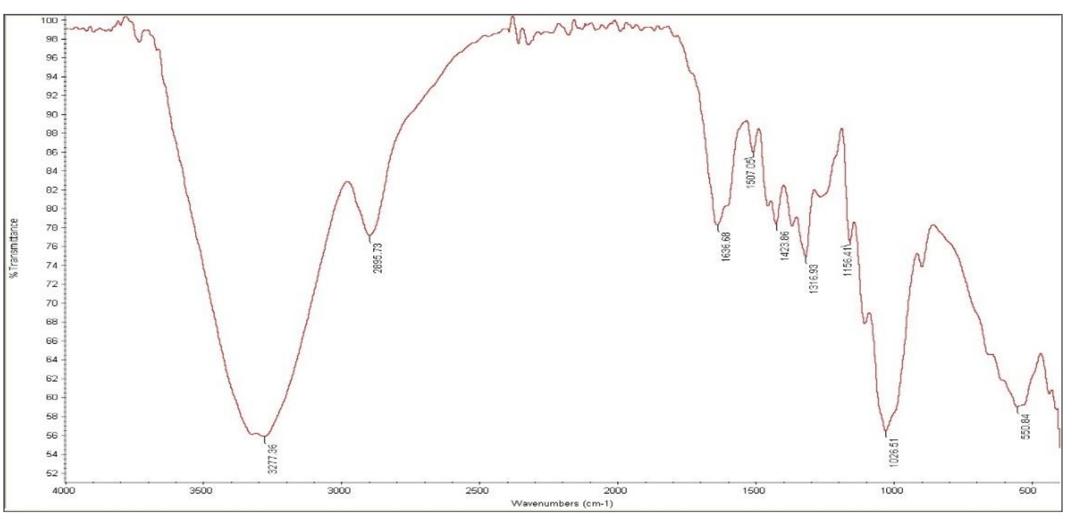
ABSTRACT

The aim of this study is to investigate the effectiveness of isora fibre mixed with 1% calcium carbonate ($CaCO_3$) as reinforcement for polypropylene (PP) thermoplastic matrix. Isora fibers were subjected to mercerization prior to blending with PP in order to obtain good interfacial adhesion with the matrix. A PP/isora composite has been prepared by melt blending of PP with 5%, 10%, 15%, 20% alkali treated Isora fibre in co-rotating twin screw extruder. The extruded strands are pelletized and then injection moulded to obtain specimens. The optimum compositions of the PP/alkali treated isora composites were mixed with 1% $CaCO_3$. Fibre-matrix adhesion will be analysed by mechanical and thermal properties of the composites were evaluated.

Graphical Abstract



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Introduction

In recent years, composites made of natural fibres have received increasing attention in light of the growing environmental awareness [1]. Also, because of their low density, good mechanical performance, unlimited availability and problem free disposal, natural fibres offer a real alternative to the technical reinforcing fibres presently available [2–6]. Natural fibres can compete with glass fibres especially with respect to the specific strength and specific stiffness.

Composites were needed in the evolution of engineering materials because, by a combination of the materials, it is possible to overcome, for instance, the brittleness and poor processability of stiff and hard polymers [7–9]. The developments in composite material after meeting the challenges of aerospace sector have cascaded down for catering to domestic and industrial applications. Composites, the wonder material with light weight, high strength-to-weight ratio and stiffness properties have come a long way in replacing the conventional materials like metals, wood *etc.* The material scientists all over the world focused their attention on natural composites reinforced with jute, sisal, coir, pineapple *etc*. primarily to cut down the cost of raw materials [10]. A composite material is defined as any substance which is made by physically combining two or more materials differing in composition or form to produce a multiphase material which possesses superior properties that are not obtainable with any of the constituent materials acting alone [11]. These constituents remain bonded together but retain their identity and properties. The constituent that is continuous and is often but not always present in the greater quantity in the composite is termed as the matrix. The second constituent is referred to as the reinforcement. It enhances or reinforces the mechanical properties of the matrix. In principle, any isotropic material can be reinforced; the reinforcing material is usually stiffer, stronger or tougher than the matrix as there has to be a good adhesion between the components. At least one of the dimensions of the reinforcement is small, say less than 500/μm and sometimes only of the order of a micron. The geometry of the reinforced phase is one of the major parameters in determining the effectiveness of the reinforcement. In other words, the mechanical properties of composites are functions of the shape and dimensions of the reinforcement [12–14].

Isora is a bast fibre presented in the bark of Helicteres isora plant. The plant occurs as undergrowth especially as a secondary growth in forests. Seed sown during the rainy season easily propagates it. Roots stem and fruits of the plant are used for medicinal applications. The stem bark is exploited for the fibre. The best type of fibre is obtained when the plants are 1-1.5 years old; plants older than 2 years yield coarse and brittle fibre. Stalks can be harvested annually for fibre extraction from regenerated shoots. It occurs as undergrowth, especially as a secondary growth in forests. It coppices well, shooting up rapidly when cut or burnt back. In some places the plant forms dense, almost impenetrable thickets covering large areas practically to the exclusion of other growths [12–17]. Polypropylene is one of the most versatile thermoplastic polymers available commercially. Mixtures of propylene and other monomers form a wide range of important co-polymers [12].

Most commercial polypropylene is isotactic and has an intermediate level of crystallinity between that of low-density polyethylene (LDPE) and high-density polyethylene (HDPE). Polypropylene is normally tough and flexible, especially when copolymerized with ethylene. This allows polypropylene to be used as an engineering plastic, competing with materials such as ABS. polypropylene is reasonably economical, and can be made translucent when uncolored but it is not as readily made transparent as polystyrene, acrylic, or certain other plastics. It is often opaque or colored using pigments. Polypropylene has good resistance to fatigue. As polypropylene is resistant to fatigue, most plastic living hinges, such as those on flip-top bottles, are made from this material. However, it is important to ensure that chain molecules are oriented across the hinge to maximised strength.

Experimental

Materials and methods

The material has been used polpropylene as grade H029HG grade (film and extrusion grade which is high density) for blending purpose, isoro fiber treated by alkaline treatment, calcium carbonate ($CaCO_3$) in Sigma alrich and treatment was processed by distilled water. Besides, isoro fiber was purchased by local trade in Chennai, India. FT-IR analysis gives the information of chemical structure through the electromagnetic spectrum using agilent cary 630 FT-IR. The range of 400 to 4000 cm^{-1} is used to take the IR spectra. The rate of extrusion of the material can be determined using a melt flow index apparatus. The material is loaded into the barrel and a constant load of 2.16 kg is used to pull out the molten material from the die. The material is melted at a temperature of 230 °C. The extrudate is collected for every 10 minutes. The values are reported as g/10 mins. Tensile and flexural properties were tested using INSTRON 3382 universal testing machine. The samples were cut into dumbbell shapes following ASTM D638 (type V) standard for tensile property, then, a load of 250 KN was applied at constant crosshead speed of 50 mm/min at room temperature. The specimen was equipped as per ASTM D790 for flexural property. The crosshead speed of 1 mm/min was used to carry out the test. Striking pendulum machine (Tinius Olsen, USA) was used to test the izod notch impact strength. The specimen was prepared as per ASTM D 256.

Results and Discussion

Fourier transforms infrared spectroscopy

The Fourier transform infrared spectroscopy (FT-IR) can give a quick and qualitative indication about change in chemical structure. The spectra of untreated and alkalization are shown in Figure 1, 2 from wave number 500-4000 cm^{-1}.

Untreated fibre

The IR spectrum of raw isora fibre shows an absorption peak at 1730 cm^{-1} which is the characteristic band for carbonyl stretching associated with the carbonyl groups present in lignin and other cellulosic components. The strong broad peak at 3300-3320 cm^{-1} is the characteristic hydrogen-bonded -OH stretching vibration. The peaks at 2910 cm^{-1} and 750 cm^{-1} correspond to the C–H and C–O stretching vibrations, respectively. A band at 1600 cm^{-1} is due to the C-C stretching of the aromatic ring in the lignin components, while a strong peak at 950 cm^{-1} arises from the glycosidic linkages. The bands at 1370, 1330, 1310 cm^{-1} are due to the –CH deformation, -OH in plane bending and $–CH_2$ wagging respectively. The band near 1250 cm^{-1} is due to the -C–O–C bond in the cellulose chain (Figure 2).

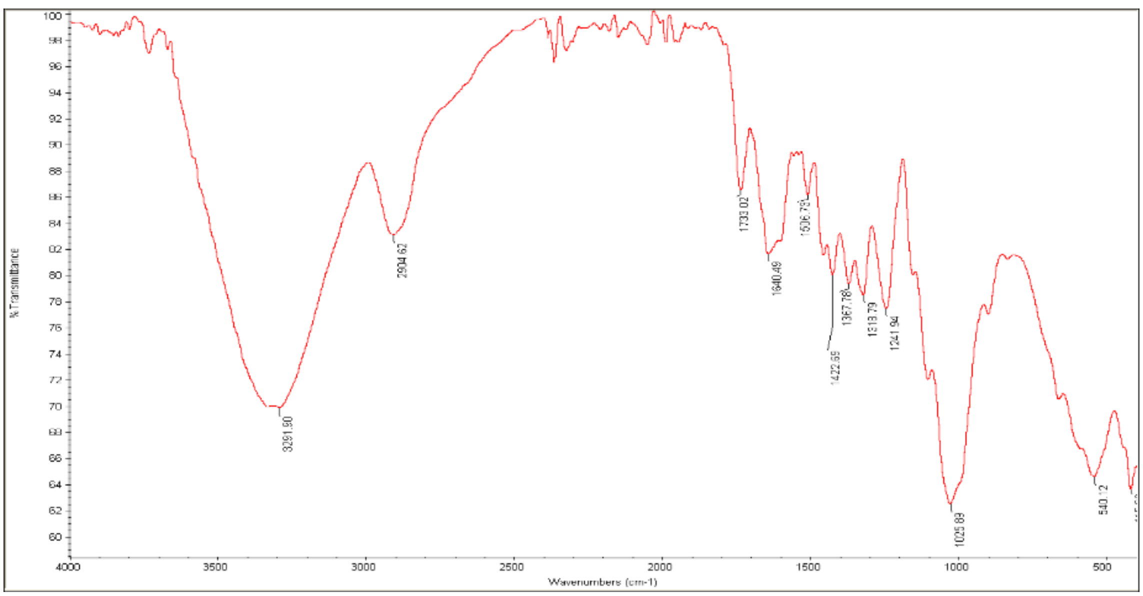

Figure 1. The FT-IR spectra of untreated isora fiber

Alkali treated fibre

The important change expected as a result of alkali treatment is the removal of the hydrogen bonding in the network which is evident from the increased intensity of the -OH peaks at 3300 cm^{-1}. Also, on mercerization, the peak at 1730 cm^{-1} in the spectrum of the raw fibre is disappeared. This is due to the fact that a substantial amount of uranic acid, a constituent of hemi-cellulose (xylan), is removed from the fibre, resulting in the disappearance of the peak. The dissolution of waxy materials

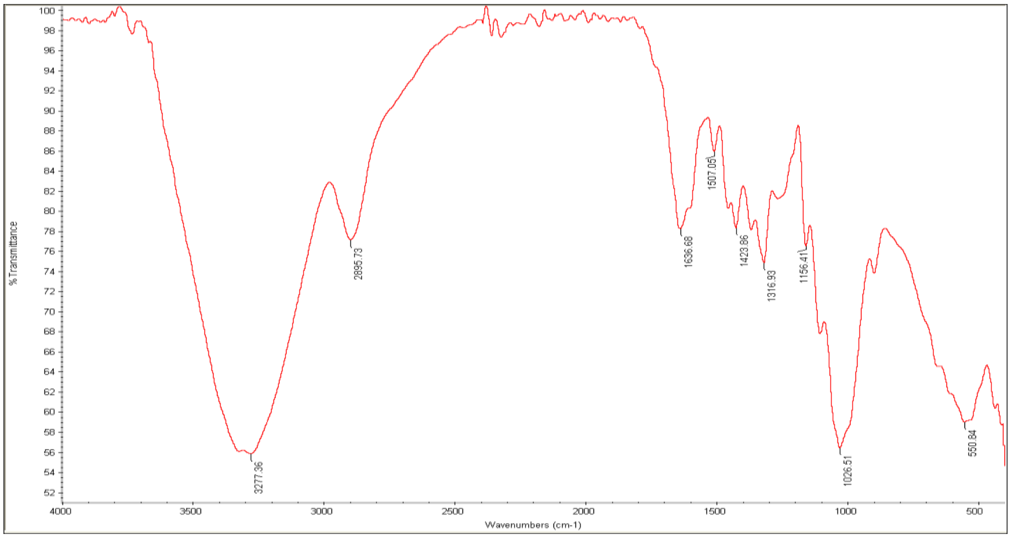

Figure 2. The FT-IR spectra of alkali treatment of isora fiber

from the fibre surface due to mercerization may cause increased mechanical interlocking between the fibre and matrix and may result in stronger composite.

Absorption bands (cm^{-1}) and their peak assignments PP (polypropylene), 973 -CH_2 Rocking Vibration 997 -CH_3 Rocking Vibration, 1167 -CH_3 symmetric deformation, 1454 -CH_2 symmetric deformation, 1167 -CH_3 symmetric deformation, 2929 -CH_2 anti symmetric deformation.

Absorption bands (cm^{-1}) and their peak assignments isorofiber compsite 1711 -C=O stretching 2723 -C–H out of plane bend, 2922 C–H stretching 1432 -C=C stretching 1377 -CH_3 symmetric deformation as shown in Figure 3 and 4.

Physical properties

The physical properties like density, water absorption and hardness for PP/isora composites mixed with 1% $CaCO_3$ at different reinforcement loadings are depicted in Table 1.

The marginal increase in the density may be due to the alkali treatment, the fibre gets denser because of the removal of hemi celluloses and lignin of the fibre, which enables the cellulose micro fibrils to come closer and enhances density. The percentage of water absorption of PP matrix has marginally increased with increase in the isora fibre content mixed with 1% $CaCO_3$. The surface hardness of PP matrix was increased with increase in the fibre content upto 20%.

Mechanical properties

Tensile strength (ASTM D 638, ISO 527)

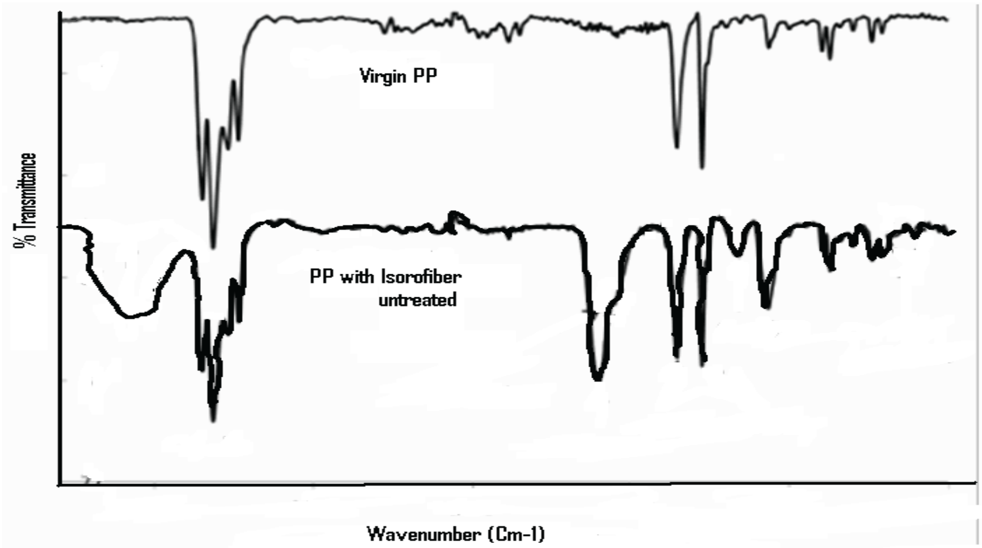

Figure 3. The FT-IR spectra of untreated isora fiber with PP

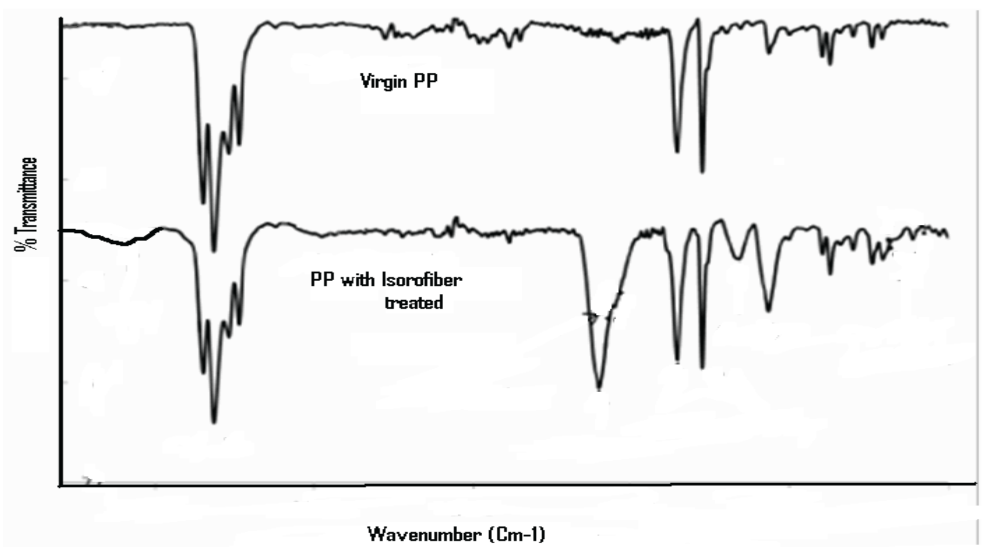

Figure 4. The FT-IR spectra of treated isora fiber with pp

The tensile strength and elongation test results of PP/isora composites mixed with 1% $CaCO_3$ (at constant level) at different filler loadings are given in Table 2. Tensile strength increased and, then, the elongation increased as the loading of fibre increases. The reduction in tensile strength, tensile elongation, modulus at 20% was observed. This is because, as the filler loading increased, the interfacial area was increased; worsening the interfacial bonding between filler and the matrix polymer, which decreased the tensile strength. In this sense, the increase in tensile properties is due to the capability of fibres oriented along tensile deformation.

Flexural properties (ASTM D 790, ISO 178)

Table 1. Physical property of PP/isora (alkali treatment) composites mixed with 1% $CaCO_3$

Composition (by wt %) PP	Composition (by wt %) Isora Fibre	Composition (by wt %) CaCO3	Density (gm/cc)	Hardness (Shore-D)	Water Absorption (%)
100	0	1	0.89	73	0
95	5	1	0.92	77	0.04
90	10	1	0.93	78	0.05
85	15	1	0.94	79	0.06
80	20	1	0.94	80	0.06

Table 2. Tensile properties of PP/isora composites

Composition (by wt %) PP	Composition (by wt %) Isora fibre	Composition (by wt %) CaCO3	Tensile strength	Tensile modulas	Elongationn (%)
100	0	1	33.0	710.2	15.8
95	5	1	34.8	799.4	15.8
90	10	1	35.8	905.5	16.5
85	15	1	36.9	1000.7	17.4
80	20	1	33.6	988.5	14.3

The flexural strength test results of PP/isora composites mixed with 1% $CaCO_3$ (constant) at different filler loadings are given in Table 3 showing that the flexural strength increased. The result of flexural strength shows that isora fibres act as rigid filler responsible for increasing the stiffness of the polymer matrix. Moreover, the extent of modulus improvement is also correlated to the fibre matrix interfacial adhesion. Whereas the decrease in flexural strength is due to more fibre to fibre interaction than the fibre matrix interaction.

Impact properties (ASTM D256, ISO 180)

The impact strength test results of PP/isora composites mixed with 1% $CaCO_3$ at different filler loadings are given in Table 4. As per the data, it was found that the impact strength of PP/isora composites mixed with 1% $CaCO_3$ increased as the loading of isora fibre increased up to 15%. When fiber is incorporated into matrix, the energy absorbing capability of fiber improves deformation and ductile mobility of polymer molecules which improve the ability of composites to absorb energy during crack propagation.

Table 3. Flexural properties of PP/isora composites mixed with $CaCO_3$

Composition PP	Composition Isora fibre	Composition (by wt %) $CaCO_3$	Flexural Stregnth (MPa)	Flextural modulas (MPa)
100	0	1	39.92	1120.35
95	5	1	44.25	1356.07
90	10	1	45.34	1558.65
85	15	1	46.60	1753.67
80	20	1	44.82	1687.89

Table 4. Impact properties of PP/isora composites mixed with 1% $CaCO_3$

Composition (by wt %) PP	Compostiion (by wt%) Isora fibre	Composition (by wt %) $CaCO_3$	Impact strength J/m
100	0	1	27.0
95	5	1	28.0
90	10	1	29.0
85	15	1	31.0
80	20	1	28.0

Conclusion

The mechanical properties of PP/isoro fiber at optimum ratio 85/15 with 1% calcium carbonate ($CaCO_3$) improved the mechanical properties. $CaCo_3$ is an inorganic hard uniform matrix in the PP with isoro fiber composites so improving the tensile, flexural and impact properties in the composites. The PP were mixed with various formulation of isoro fiber. Consequently, there is no much difference in the mechanical properties but 1% $CaCO_3$ incorporated in the PP has been mixed with isoro fiber to improve the properties. This is the corresponding result of the mechanical properties of tensile strength and elongation.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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